# Estimation of secondary neutron dose in proton therapy using multicollisional and Pauli-blocking constrained Monte Carlo calculations

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Neutrons contribute to dose deposition in critical organs outside the irradiated target volume. However, the literature regarding neutron dose from proton therapy is limited. This issue is of special relevance for young patients, particularly when life expectancy is long.Previous estimates have been based mainly on calculations using the FLUKA code[1,2]. In this work we have used a quite sofisticated multi-collisional Monte Carlo code (MCMC), developed in our group, which takes into account Pauli-blocking effects in a novel and more precise way[3]. Thus we have obtained spectra and multiplicities for neutrons emitted in the reactions: p+C, p+O, p+Ca and p+N, for proton energies from 100 to 200 MeV. When compared to the ICRU evaluation[4], our results show a slight shift of the spectra towards higher energies, and neutron multiplicities a factor of $\sim 2$ smaller. This is somewhat expected, since a more rigorous Pauli-blocking constrain favours higher energy states and restricts the number of available exit channels. Because neutron delivered doses are proportional to average neutron multiplicities, estimates that didn't take properly into account Pauli-blocking effects may have greatly overestimated the dos outside the target. Therefore, we suggest tha the risk from secondary neutrons may be lower than originally assumed, while reccomending further verification.

The art of cancer treatment is findig the right balance between tumor control and injury to normal tissues[5].

**References**

[1] A. Fass et al., Nucl. Instr. Meth. in Phys. Res. A332, 459 (1993).
[2] A. Ferrari et al., Nucl. Instr. Meth. in Phys. Res. B71, 412 (1992).
[3] T. E. Rodrigues et al., Phys. Rev. C (submitted).
[4] ICRU 2000 Nuclear data for neutron and proton raditherapy and for radiation protection, Report 63.
[5] A. L. Boyer et al., Phys. Today, 55 (9) 34 (2002).

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